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PETROLOGIC INVESTIGATIONS IN THE RIES: VARIEGATED BRECCIA

Wolf v. Engelhardt, Dieter Stoeffler, Werner Schneider

Translation of Petrologische Untersuchungen im Ries, "Bunte Breccie," contained in: Geologica bavaria (Bavaria, Geologisches Landesamt), Munich, No. 61, 1969, pp. 276-284

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16. Abstract
The variegated breccia appears to represent an inversion of the original primary deposit, based on the fact that lower stratigraphic layers appear more frequently in the upper parts of the breccia. Portions if the breccia from the crater are from zones in which the maximum shock wave pressure did not exceed 500 kbar.

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PETROLOGIC INVESTIGATIONS IN THE RIES: VARIEGATED BRECCIA

Wolf v. Engelhardt, Dieter Stoeffler, Werner Schneider

2.2.1 General /276*

The following report is based in preliminary results from a not yet complete dissertation on the variegated breccia.

As the investigations refer primarily to the mineralogic composition, the geological works reported by Preuss (1964) should be referred to for the macroscopic description of the variegated breccia. In particular, see the work of Hüttner (1958), who has described the variegated breccia in detail and compared it with other breccias of known origin.

2.2.2 On the Distribution of the Detritus / 277

On the basis of the geological maps which have been available, the distribution of suevite, the crystalline detritus, the Keuper rocks which can be represented on the geological map, the variegated breccia and the great Malm rocks corresponds in major lines with a statement by Schröder and Dehm (1950) that steadily younger rocks prevail as the greater allochthonous rocks with increasing distance from the center of the Ries.

Suevite occurs predominantly near the margin of the center of gravity as the deepest primary stratigraphic unit. It appears to be distributed at the surface only in the form of isolated

* Numbers in the margin indicate pagination in the original foreign text.

"sprinkles". The crystalline detritus, which stems from similarly deep position, also lies predominantly near the margin, except for two narrow strips (Appetshofen/Bissingen and Appetshofen/Itzing). The mapped Keuper rocks also show a similar distribution.

In contrast, the variegated breccia has a superficial and basically wider distribution extending to the more distant Vorries. The allochthonous Malm rocks have a similar wide distribution.

2.2.3. Particle Size Distribution in the Variegated Breccia

The distribution curves in Figure 30 show a wide variation of particle sizes appearing in the variegated breccia. At the same time they show only minor differences in the shapes of the curves. This suggests good mixing of the constituents (stones) which make up the composition of the variegated breccia. The particle size distributions shown are certainly influenced by the preparation, as the larger clay-marl and clay-sand particles are destroyed in the preparation.

The integrated particle size curves shown in Figure 31 show poor classification, corresponding to good mixing, by their low slope with very large classification coefficient $(s = \sqrt{Q_3 / Q_1} = 6.3—14.2)$.

The skewness coefficient, $sk = \dfrac{Q_1 \cdot Q_2}{Md^2}$, is between /278

1.6 and 6.2, showing a strong predominance of the coarser fractions.

2.2.4 Mineral Composition of the Rock Components of the Variegated Breccia

The rocks of the crystalline bedrock and the sedimentary formations which make up the variegated breccia provide the

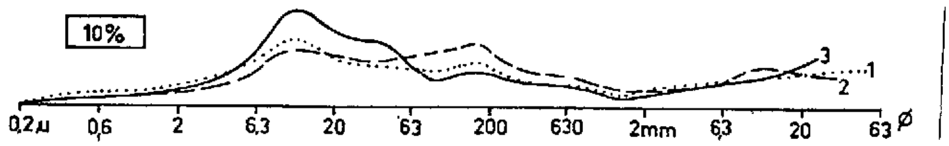

Figure 30. Particle size distribution curves for the variegated breccia from Otting.

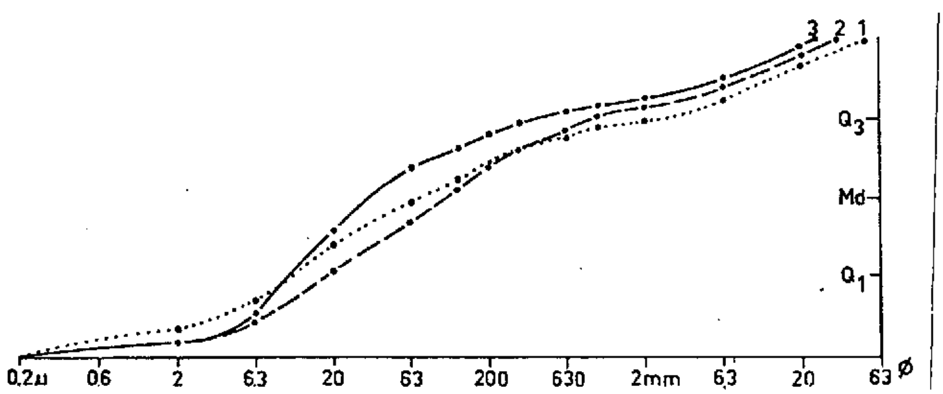

Figure 31. Integrated particle size curves for the variegated breccia of Otting.

minerals of the finer particle fractions. From characteristic zonal minerals we can make conclusions about the proportions of the individual formations in certain samples of the variegated breccia.

In the following, the minerals of the various stone types of the Ries bedrock which can appear in the sand fractions of the variegated breccia are enumerated.

Crystalline: The rocks of the crystalline bedrock provide the light minerals quartz, orthoclase, microcline and acidic to intermediate plagioclase, as well as small proportions of muscovite and cordierite. The heavy minerals, in the sequence of decreasing frequency, are garnet, apatite, titanite, zircon, and rutile, as well as amphibole, biotite, pyroxene, epidote and sillimanite.

Keuper: According to our own, still incomplete investigations, the sandstones of the middle Keuper contain, aside from quartz, the feldspars, primarily microcline and orthoclase. The heavy minerals which occur are garnet, zircon, tourmaline, rutile, apatite; and secondarily, brookite, anatase and staurolite.

Lias: Only very small proportions of quartz, feldspar, glauconite and carbonate can be expected out of the weak sandstone, lime sandstone, and limestone layers of the predominantly clayey Lias.

Dogger: The Dogger beta sandstones yield quartz and only a very little potassium feldspar. The gamma to epsilon layers yield predominantly oolitic limestones. Zircon, tourmaline, rutile, staurolite, garnet have been mentioned as heavy minerals; and, as rarely occurring ones, anatase, brookite, epidote, titanite and barite (Schröder, 1962). We must expect a small amount of glauconite from the Dogger zeta. As opaque heavy minerals, goethite, hematite and siderite from the clay ironstone geodes and iron ooliths of the Lias and Dogger can play a considerable part.

Malm: Marl limestone and limestone should be expected from the Malm.

High Sands: The high sands of Monheim, etc., which are certainly post-Riesian, cannot be components of the variegated breccia. Investigations on their mineral composition are in progress.

Pre-Riesian Tertiary: South of the Burdigal cliff line we can expect high proportions of quartz and feldspar from sands of the upper sea molasse* in the variegated breccia. The heavy minerals include epidote, chlorite, garnet, hornblende, apatite and zircon, as well as glauconite as another typical mineral (Lemcke, v. Engelhardt and Füchtbauer, 1953).

In addition to the often observed limnic and terrestrial carbonate rocks, upper-oligocenic fresh water channels and the old-upper-miocenous pisolith chalks, on the eastern to southeast Vorries there are tertiary sands which make up the variegated Breccia. This produces a substantial increase in the quartz and feldspar content (Dehm, 1931). These sands and those mentioned by Nathan (1925) east of Monchsdeggingen have the same facies as the sands of the upper fresh water molasse, according to Schetlig (1962). These often occur on the Donauworth plat and they also extend outside of the northern border of this plat. According to Bizier (1969) there are sediments of the upper fresh water molasse in the south-eastern and eastern Vorries whose heavy mineral paragenesis consists of garnet, epidote, staurolite, apatite, tourmaline, zirconium, hornblende, disthene, zoisite and titanite (Lemke, v. Engelhardt and Fuchtbauer 1953).

* Translator's note: Soft sandstone.

The oolitic ores formed in the Eocene can occur in large amounts in places as opaque "heavy minerals".

One can subdivide the sequence of the rocks in the Ries bedrock into the following two units according to the mineral composition:

a) a lower unit (crystalline Dogger beta) in which the sum of quartz + feldspar far exceeds the limestones (15:1 without considering the crystalline!), and
b) an upper unit (Dogger gamma Malm pre-Riesian old tertiary) in which only carbonates occur, aside from pre-Riesian tertiary sands.

To be sure, an admixture of tertiary sands could obliterate the almost purely carbonate character of the upper unit, but it should be recognizable through the heavy minerals stemming from the Alps (epidote, zoisite, disthene, staurolite).

As the feldspar content in the crystalline rocks is usually considerably higher than in the sandstones, increased participation of crystalline will generate an increase in feldspar. High proportions of plagioclase likewise indicate crystalline, because potassium feldspars predominate in the sandstones, according to observations which have been made. Of the heavy minerals, titanite, hornblende and biotite are typical of the crystalline.

2.2.5 Mineral Composition of Individual Appearances of the Variegated Breccia

In the following, we report on the stone inclusions (over 2 mm diameter) and on the mineral composition of the 63-125 μ sand fraction of individual appearances of the variegated breccia. The investigation of all the other fractions is going on. So far, we have results of clay mineral investigations only from Otting.

Otting (11700/16050): (1)

At present, the variegated breccia is disclosed in the central part of the Suevite fissure at the W and E wall with the hanging wall toward the Suevite. The first glasses appear already 0-15 cm below the base proper of the lower quenched zone of the Suevite in still typical variegated breccia in the part of the west wall investigated. The upper parts of the variegated breccia are more strongly fixed in places at the same wall by a secondary carbonatic bonding agent. /280

The following rocks can be observed as inclusions of more than 2 mm diameter in the sequence of decreasing frequency: limestone and marl limestone of the Jura; sandstones and marl of the Keuper, Jura clays, crystalline, and to a small extent, Dogger sandstone, clays and carbonates of the tertiary (see

(1) Rightward and upward coordinates of the 1:50,000 topographic map.

Wagner, 1965).

The 2 m long profile at the west wall was investigated using 7 samples. From bottom to top there was a decrease in the ratios of quartz to feldspar and orthoclase to plagioclase. The ratio quartz + feldspar / Jura limestone increased upward. The occurrence of quartzes with planar elements, in proportion continuously increasing toward the suevite, with small variations, indicates that material stressed by shock waves is also mixed in. The total carbonate content shows a small maximum at the base of the profile and at the top of the variegated breccia. The latter is conditioned by the secondary cementing. At the suevite base the carbonate content decreases to 0%, presumably due to dissolution by descending solutions.

The distribution of the heavy minerals shows no characteristic development in the profile. The great fluctuation of the biotite and hornblende contents at approximately constant proportions of titanite, garnet, zircon, apatite, tourmaline, rutile and epidote is striking. While biotite, hornblende and titanite are derived primarily from crystalline rocks, the epidote-staurolite paragenesis, occurring only to a very slight extent, betrays a weak participation of tertiary sediments.

The clay mineral investigations show the prevalence of illite and kaolinite as compared to a mineral of the montmorillonite group. This differentiates the variegated breccia from suevite, in which montmorillonite predominates with very small proportions of illite and kaolinite.

In a biotite-carrying granitic rock, as in the particle preparations, quartz with planar elements as well as partially isotropized feldspars could be demonstrated as shock wave indicators.

Aumühle (99800/26800):

In the suevite fissure, the variegated breccia is overlaid by a suevite covering with a very rough relief (see Wagner, 1965). The variegated breccia consists predominantly of large rocks of Jura clays and Keuper material. The red marl and sandstone of the Keuper are above the clayey sediments of the Jura. An isolated heterogeneous-breccious rock 50 cm below the suevite base contains Keuper sediments also, in conformity with the light and heavy minerals. Directly below the suevite there is a 0-20 cm thick breccia with distinct parallel texture. Due to the steep relief, it could have originated through partial movements of the suevite deposited on top of it.

The investigations of the samples from the breccious rocks, the breccious deposit above the variegated breccia, and from the suevite itself showed, as in Otting, a decrease of the ratios of the minerals quartz/feldspar and orthoclase/periclase and of the total carbonate content from bottom to top. The proportion of quartzes with planar elements and the ratio quartz + feldspar / Jura limestone increase toward the suevite.

The increase of garnet and biotite from bottom to top and the decrease in the same direction of the heavy minerals zircon, tourmaline, brookite and anatase which characterize the Keuper sandstones, with approximately constant proportion of apatite + barite indicate an enrichment of crystalline material in the upper part of the profile.

Ronheim (04300/07300):

Above the autochthonous and scarred white Jura delta lie a maximum of 10 m of well mixed variegated breccia with large rocks of Keuper marls and sandstones, Jura limestones and clays, Dogger sandstone and tertiary sediments (see Wagner, 1964, p. 567). In the fractions of 2 - 6.3 mm diameter and 6.3 - 20 mm diameter, according to existing investigations, the sediments of the Keuper, the Dogger beta and the crystalline participate at least as strongly as the Jura limestones and clays and the tertiary sediments.

As in Otting and Aumühle the mineral ratio for quartz/feldspar in the profile studied decreases from bottom to top. In contrast to these two disclosures, the ratio potassium feldspar/plagioclase /281 increases. This can be explained through the high microcline content of the Keuper sandstones. The ratio quartz + feldspar / Jura limestone and the total carbonate content show no characteristic change in the Ronheim profile. As in the other profiles, the content of quartzes with planar elements increases from bottom to top.

Along with the heavy minerals garnet, zircon, tourmaline, rutile, anatase, brookite, apatite and barite, which occur with only minor fluctuations in the samples investigated, there appeared epidote, zoisite, staurolite and disthene, some glauconite and, in very small proportions, the typical molasse heavy mineral paragenesis. The large biotite content, partially deriving from the crystalline, fluctuates very strongly and can reach a maximum of 45 times the sum of all other heavy minerals.

Planar elements in quartz and partially isotropized feldspars were also observed in biotite-carrying granitic rocks.

Gundelsheim (14850/19550):

The variegated breccia lies at a maximum thickness of 7 m upon autochthonous scarred white Jura delta (see Wagner, 1964, page 573). Jura limestones and tertiary clays predominate by far in the fractions above 2 mm diameter, followed by Jura clays and very small proportions of crystalline and Keuper material. The matrix of the variegated breccia consists primarily of the yellow-brown and gray tertiary clays. Well-rounded white Jura pebbles could be observed repeatedly.

In comparison to the profiles described previously, the quartz and feldspar contents and the proportion of quartzes with planar elements are strikingly reduced in favor of the carbonates. The mineral ratios mentioned above and the total carbonate content show no characteristic development in the profile investigated.

Except for the highly fluctuating biotite and chlorite contents, the heavy mineral composition is quite constant, as in the other samples. Along with a distinct garnet dominance there appear principally epidote, staurolite and disthene, indicating participation from sediments of the upper sweet water molasse. This observation is particularly interesting because in our opinion such a northerly appearance of molasse sediments shed from the Alps area was not previously known. Rutile, tourmaline, zircon, apatite and glauconite occur in small amounts. In contrast to the other samples carrying very little chlorite, the chlorite predominates with approximately constant biotite/chlorite ratio. The chlorite, like the glauconite, can have derived from the molasse.

Completely isotropized quartz and feldspar were detected in a granitic rock.

Möhren (17200/23200):

A maximum of 6 m of variegated breccia lie above autochthonous scarred white Jura delta. The same macroscopic description applies as for the Gundelsheim profile. Here, too, worked-up pre-Riesian white Jura pebbles could be demonstrated as inclusions in the variegated breccia.

As in Gundelsheim, and in comparison to Otting, Aumühle and Ronheim, the proportion of shocked quartz is reduced in favor of the carbonates. The individual mineral ratios and the total carbonate content show no characteristic development within the profile, except for the ratio quartz + feldspar/Jura limestone, which increases from bottom to top.

Epidote, staurolite, disthene and glauconite appear along with garnet, zircon, tourmaline, rutile and apatite. Except for the content of biotite and chlorite, which decrease continuously from bottom to top, the relative amounts of the heavy minerals do not change significantly in this profile.

Zipplingen (03400/22100):

The variegated breccia, disclosed a maximum of 2 m below the suevite consists almost solely of severely triturated crystalline with very small participation of Jura clays, Keuper material and traces of tertiary brown coal clays. The transition from the variegated breccia to the suevite shows a relatively continuous / 282
character. Also, the first glass bombs of the lower scarred zone of the suevite already appear to be included in the variegated breccia. Quartz and feldspar appear in approximately equal proportions. The entire variegated breccia is free of carbonate.

In this profile, too, the quartzes with planar elements increase from bottom to top. Garnet and epidote were detected along with the heavy minerals biotite and hornblende, which are typical of the crystalline rocks.

Quartzes with planar elements and partially isotropized feldspars can be observed in biotite-carrying granitic and hornblende dioritic rocks.

Guldesmühle (99950/95000):

Above autochthonous sands of the OMM, which were plowed up by Ries detritus, there follow 1.5 - 3 m of variegated breccia, overlaid by severely broken up limestone lumps (see Hüttner, 1958, p. 204). Along with the greatly predominant worked up sandy and clayey-marl molasse sediments, Malm limestones and, to a smaller extent, also crystalline, red Keuper marl and Jura clays participate in the composition of this variegated breccia. While the basal portions of the variegated breccia, conditioned by the worked up sands, contain only a little carbonate with a high quartz and feldspar content, the proportion of carbonate becomes greater in the direction of the overlying Malm limestone, at the expense of the quartz and feldspar content.

Garnet and epidote predominate among the heavy minerals. Staurolite, disthene, tourmaline, rutile and apatite occur only in small amounts. Chlorite and glauconite are frequent.

Completely isotropized quartz and feldspar were demonstrated in a biotite-carrying granitic rock.

Dischingen (01000/96350):

At the south wall of the rock fissure in a large, sandy, allochthonous massive limestone there is a breccia in an approximately vertical column, disclosed for a length of about 2 m. It has an irregular cross section, and consists essentially of a finely ground hornblende-dioritic rock, with a smaller proportion of Jura limestones and clays.

Along with the light minerals quartz, intermediary plagioclase and carbonate, there appear as heavy minerals only hornblende (98%) and apatite (2%). Keuper, Dogger and Tertiary sediments, therefore, to not appear to be involved.

Isotropized plagioclase was observed in a hornblende-dioritic rock.

2.2.6 Types and Petrographic Composition of the Variegated Breccia

Because of the varying mass ratios of sedimentary and crystalline material, the variegated breccia is linked with the crystalline detritus material through transitions so that it can be difficult in many cases to draw any sharp boundary between the two formations. The absence of fusion products characteristic of suevite is common for all these detritus masses.

The occurrences of the variegated breccia which have been investigated can be ordered into 4 types:

Type 1: Detritus masses from the crater, without admixture of sediments occurring at the site of deposition (Aumühle, Zipplingen).

Type 2: Detritus masses predominantly from the crater, mixed with worked up Vorries sediments (Ronheim, Otting, Gundelsheim, Möhren).

Type 3: Detritus masses predominantly from the tertiary Vorries sediments plowed up by Malm limestone rocks, with small portions of material from the crater (Guldesmühle).

Type 4: Variegated breccia filling cracks in allochthonous Malm limestones (Dischingen). / 283

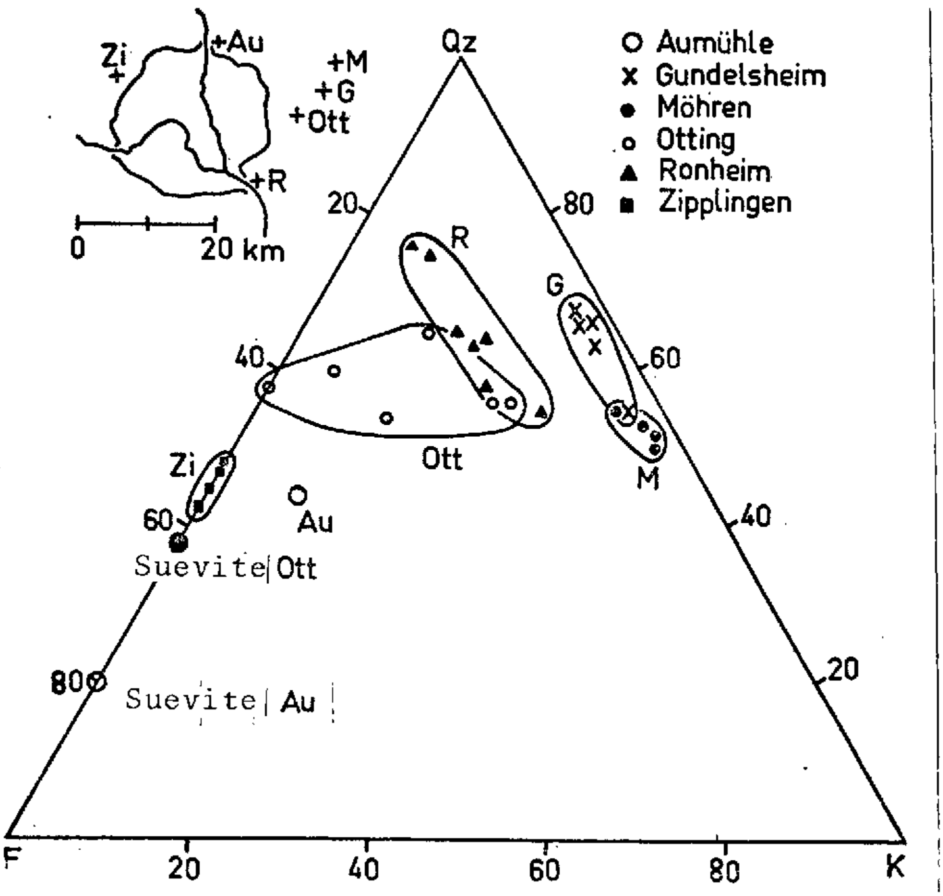

Figure 32. Quartz-Feldspar-Carbonate diagram (63-125 $\mu\phi$).

The mineral composition, which is by no means similar, shows that the variegated breccia is not a uniformly composed mass in the entire Ries region. According to the results so far, systematic changes in the mass ratios of the rock types making up the variegated breccia are indicated both in the vertical and in the lateral direction. The decrease of the quartz/feldspar ratio from bottom to top, frequently observed in the profiles, and the increase in quartzes with planar elements and in the quartz + feldspar / carbonate ratio in the same direction suggest a stronger participation of

stratigraphically deeper rocks in the upper parts of the variegated breccia. This is particularly distinct in the profiles near the edge of the Ries, which contain little Vorries sediments. In the Gundelsheim and Möhren disclosures, which are more distant, the mineral ratios, except for the quartz + feldspar / carbonate ratio, are presumably affected by the worked up Vorries sediments so that a corresponding decision is not possible. Thus, at least in the profiles near the edge of the Ries, the variegated breccia appears to represent an inversion of the primary deposition. Also, the suevite, with predominantly crystalline composition, always lies above the variegated breccia, which consists predominantly /284
of sediments.

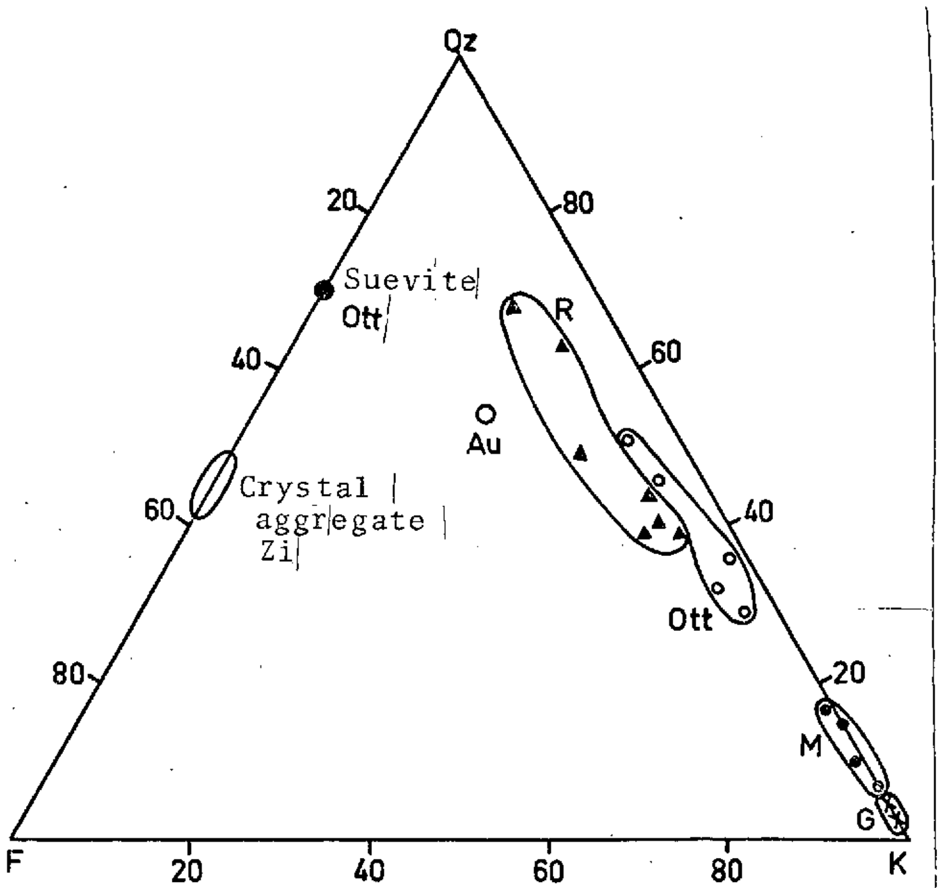

Figure 33. Quartz-Feldspar-Carbonate diagram (1-2 mm diameter).

A comparison of the mineral contents of the various disclosures (Figures 32 and 33) shows that the participation of the individual rocks in the structure of the variegated breccia is also different laterally. There is an obvious distinct dominance of the stratigraphically deeper units near the Ries, while with increasing distance from the Ries center the stratigraphically higher formations play an increasingly greater role. This fact agrees with the observations of Schröder and Dehm mentioned initially, that among the large allochthonous rocks, the younger rocks increase with increasing distance from the center.

The occurrence of diaplectic (i. e., altered by shock waves) quartz and feldspar in the variegated breccia is important for reconstructing the occurrence of the Ries. Differing from the minerals of the crystalline fragments appearing in the suevite, the shock wave stage II at most has been detected in quartzes and feldspars from the variegated breccia. Therefore the parts of the variegated breccia derived from the crater come from zones in which the peak shock wave pressure was in any case not greater than 500 kbar.